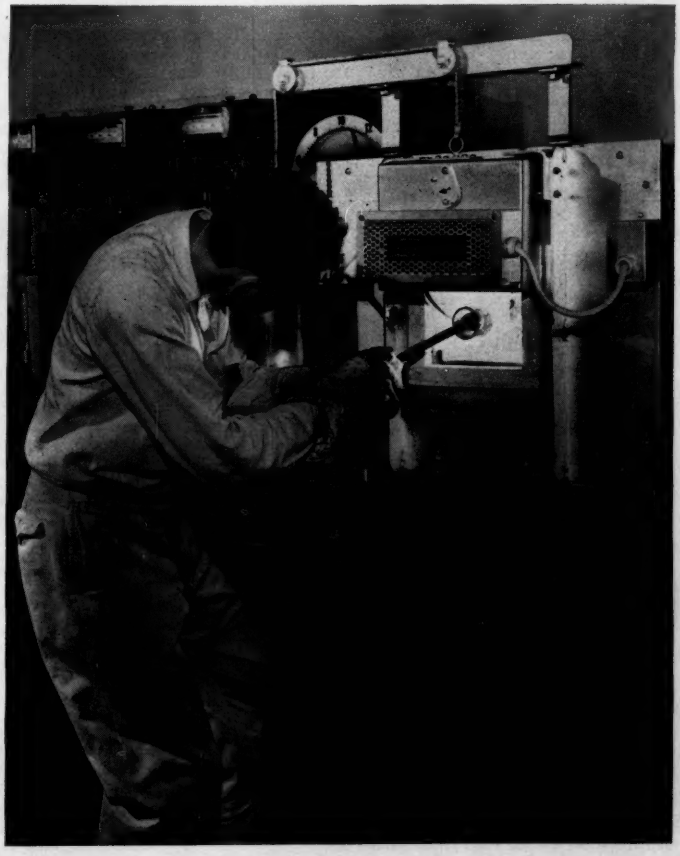
STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

MAY ATLANTA, GEORGIA 1950



The Research Engineer

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RESEARCH PUBLICATIONS

One of the most important services which a technological institution can render is the publication of the results of its scientific and engineering research investigations. Even private industry, today, has come to realize that a free exchange of information, through publications, is of far greater benefit to each company than strict retention of all data, regardless of significance. What little immediate assistance is rendered to competitors is more than compensated by the use of knowledge reported by others.

As regards information obtained at universities, the obligation to report the results of investigations is even greater, consistent, of course, with contractual obligations on those studies conducted specifically for private companies. Through graduate theses, information is rendered on those investigations undertaken in the training of research-minded advanced students — studies often of important fundamental significance. Through the publications of faculty members, the knowledge obtained by qualified, inquisitive scientists and engineers is made available to all.

Finally, through the publications of engineering experiment stations and similar groups, information is rendered on a wide variety of professional-level investigations undertaken to find new uses for raw materials, to advance the horizons of knowledge in specific fields, and to solve specific industrial problems. At the Georgia Tech Engineering Experiment Station, for example, five media are employed—*bulletins*, to make available in detail the results of Station research studies; *reprints* of articles published in technical and scientific journals by members of the Station's staff; *circulars*, which present important information not otherwise readily accessible; *special reports*, which include literature searches and economic studies; and THE RESEARCH

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Industrial and governmental research in engineering institutions of higher learning such as Georgia Tech is carried out side by side—and often with the same personnel—with the fundamental or basic research usually associated with graduate training and the scientific curiosity of technical faculties. This arrangement offers numerous advantages both to industry and education. To the industrialist, such a plan makes available the best in facilities and scientific talent for the solution of technical problems; to the educator, it affords a better understanding of the problems of industry and government as they affect the training of students; to the graduate student, it provides opportunities for participation in actual research in his chosen field; to the university as a whole, this program helps to make available a larger and more research-minded faculty, combined with the subsequent opportunity to render increased service to its area and to the nation.

BLAKE R. VAN LEER
President, Georgia Institute of Technology

METALLURGICAL RESEARCH AT GEORGIA TECH

By R. J. RAUDEBAUGH*

Through the cooperation of the Engineering Experiment Station and the various schools and departments at Georgia Tech, specialized laboratories have been created in many fields in recent years. The following article describes new facilities here in the field of physical metallurgy and details some of the research and educational goals envisioned.

Physical metallurgy, particulary as it relates to the selection and fabrication of existing metallic materials and the development of new alloys and processing techniques, is an integral phase of an adequate engineering educational and research program. In the Southeast in particular, the recent growth in industrial activity has brought with it many challenges in the metallurgical field, challenges which are being met at the Georgia Institute of Technology through increased metallurgical course offerings at the graduate level and through initiation of research programs.

A sequence of three quarters of graduate work is now available, designed for the student who has had a minimum of two quarters of introductory work in this field. This program provides training in the theory basic to metal and alloy behavior (Theoretical Physical Metallurgy); the study of the microstructural characteristics and associated engineering properties of metals and alloys as influenced by processing variables (Metallography); and an analysis of metal working processes (Applied Physical Metallurgy).

Facilities for laboratory instruction and research, which are housed in the School

* *Professor of Chemical Engineering.*

Figure 1. James E. Curry, graduate student, at the Bausch and Lomb research metallograph.

of Chemical Engineering, include (1) gas-fired and induction melting furnaces; (2) electric resistance heat-treating furnaces with adequate instruments for temperature recording and control; (3) a complete metallographic laboratory, whose research metallograph is shown in Figure 1; (4) physical testing equipment for such properties as hardness (Rockwell, Brinell, and Bergsman), impact, and rotating-beam fatigue, and universal hydraulic machines; and (5) a nondestructive magnetic inspection unit (Magnaflux). Available in other localities on the campus are an electron microscope and X-ray diffraction and spectrographic equipment. Under the direction of competent specialists, these additional research tools are available for use in the study of metal problems.

BERGSMAN TESTER

The Bergsman microhardness tester, shown in Figure 2, is of particular interest as a research tool. This instrument, mounted on the stage of the Bausch and Lomb metallograph, permits an accurate study of penetration or scratch hardness of various microconstituents in an alloy.

A specimen prepared for microscopic examination is clamped in the specimen holder (shown at 1 in Figure 2), and counterbalancing adjustments (6 and 7) are then made. A selected load (5) is placed on the platform (2) directly over the penetrator, as indicated by the locating arm (8). The platform is mounted on a lever (3) which pivots about a small pin (4).

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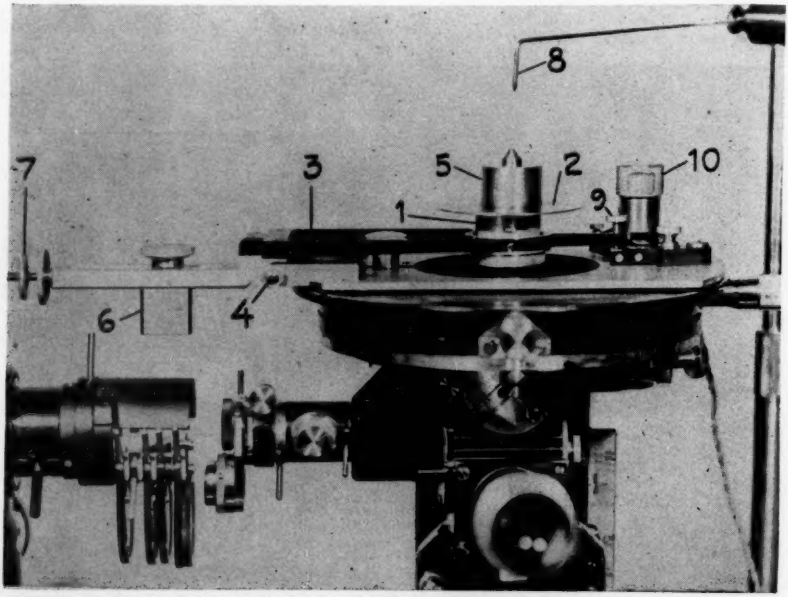

Figure 2. Bergsman microhardness tester clamped in place on the stage of an inverted microscope.

1. *Specimen holder.*
2. *Load platform.*
3. *Lever*
4. *Pin, about which lever 3 pivots.*
5. *Load.*
6. *Counterweight.*
7. *Auxiliary counterweight.*
8. *Loading arm.*
9. *Circuit contact attached to lever 3.*
10. *Light.*

GRAPHICAL AND MECHANICAL METHODS OF COMPUTATION

By W. H. BURROWS*

Fundamental research on nomography and related methods of computation has for some time been one of the fields of endeavor of the Engineering Experiment Station. The following article by W. H. Burrows, chief researcher on these subjects at Georgia Tech, presents background information on a fascinating and highly useful science.

Only a few years ago, emphasis among mathematical adjuncts of the engineering fields was directed toward the development of simplified mathematical operations and approximate methods which could be adapted to the limited calculating devices of that day. Now, emphasis is shifting rapidly toward the design of mathematical devices capable of rendering solutions of problems of increasing complexity. As a result, modern engineers have at their disposal a choice of calculating devices ranging from simple hand-operated counters to complex "mechanical brains" capable of solving involved differential equations, evaluating difficult integrals, and otherwise replacing many a well-heeled cerebral cortex for active duty in more inspiring fields.

MATHEMATICAL MACHINES

If the term *mathematical machine* were to be applied literally, it would include any mechanism whose parts are constrained to move in such a manner as to conform to certain mathematical concepts and, by their motion, to provide information concerning those concepts. The slide rule and the nomograph are usually excluded from this category, although the above definition excludes very little. The abacus is included, as are the adding machine, the "calculating machine" commonly used for multiplication and division, various electrical assemblies, and continuous operators consisting of banks of mechanical and/or electrical assemblies. An excellent resume of this field and its theoretical bases has been given by Murray.[15]

Since many of these devices register their results on counters with eight, ten, or more possible digits, the degree of accuracy is limited primarily by the errors of the original data. However, accuracy comes high, and the expense of such machines is too great to permit their application in many routine calculations. Furthermore, such machines, like typewriters, become more a burden than a help in the hands of inexperienced operators. Many of these machines —particularly those employed for preparing tables of values of various functions—must be fed their basic data in code form, such as punched cards or tapes, so that preliminary preparations for a run may require many hours of skilled labor.

SLIDE RULES

The slide rule is a device for adding or subtracting, although it is virtually never used for these purposes. Its principle may be exemplified by placing two foot-rules edge-to-edge so that Rule A has its zero opposite 4 on Rule B (Figure 1). Then 2 on Rule A will lie opposite "6" (2 + 4) on Rule B, etc.

The use of logarithmic scales instead of linear scales transforms the slide rule into

*Assistant Professor of Chemistry.

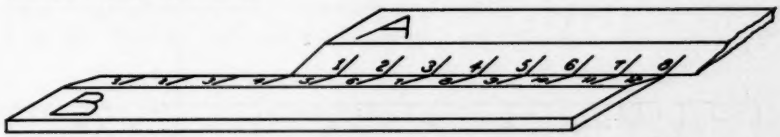

Figure 1. The slide rule principle exemplified by addition of linear displacements.

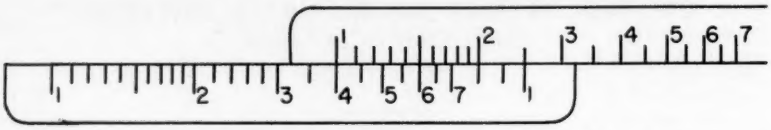

Figure 2. Slide rule with logarithmic scales for multiplication.

a multiplier instead of an adder (Figure 2), since log a + log b = log ($a \times b$). The use of log scales of different lengths makes the slide rule both a squarer and a cuber, as well as a multiplier (Figure 3). The introduction of log-log scales enables the slide rule to raise numbers to all possible powers, although it loses its ability to multiply those powers directly, since the results appear on the log-log scales rather than on the log scales (Figure 4).

Special scales may be introduced to eliminate reference to tables of values; thus, one of the log scales may be replaced by a scale derived from values of log sine x or log tan x for trigonometric calculations, log $\sqrt{x}$ or log $\sqrt[3]{x}$, log $1/x$, log sinh x, log tanh x, etc. In a sense, such rules are "special," since they are designed for a limited field of operation. However, these scales are in such wide demand that they have become standard equipment on many rules.

All of the calculations which may be performed on the slide rule may be reduced to the simple form of $A + B = C$. Thus, 4.35 sinh 2.05 = 1.67 becomes log 4.35 + log sinh 2.05 = log 1.67. The expression $1.056^{0.355} = 1.0195$ becomes log 0.355 + log (log 1.056) = log (log 1.0195), etc.

Special Slide Rules

Slide rules of the type $A + B = C$ are frequently simplified to the form of special slide rules for the solution of particular formulas. An example of a special slide rule is shown in Figure 5. The formula involved is the Doolittle formula,

$$H = 4.35\ (S + 6.13)^{0.55}\ U^{1.35} + 563.$$

Solution by ordinary slide rule involves the following steps: (1) adding S to 6.13 (not a slide rule operation), (2) raising the sum to the 0.55 power (log-log operation), (3) raising U to the 1.35 power (log-log operation), (4) multiplying the S and U terms together (log-scale operation), (5) multiplying their product by 4.35 (log-scale operation), and (6) adding 563 (not a slide rule operation).

Four of these steps are discontinuous; i.e., their results must be transferred to other scales for subsequent operations. If a series of runs results in five possible values each of S and U, which must be taken in their 25 possible combinations to determine values of H, the computations become quite laborious and susceptible to error. To eliminate these, a special slide rule may be constructed by setting A = 0.55 log (S + 6.13), B = 1.35 log U, and C = log (H − 563) − log 4.35; whence, $A + B = C$. The value of H is then

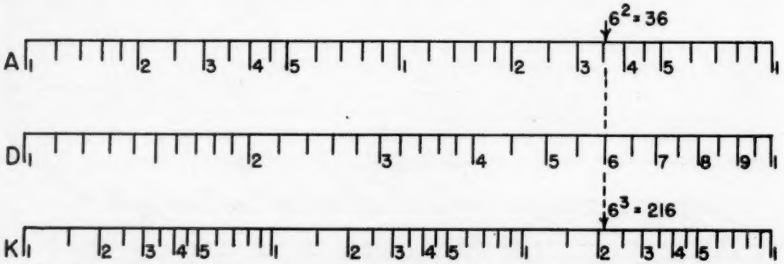

Figure 3. Slide rule with A-scale for squares and K-scale for square roots.

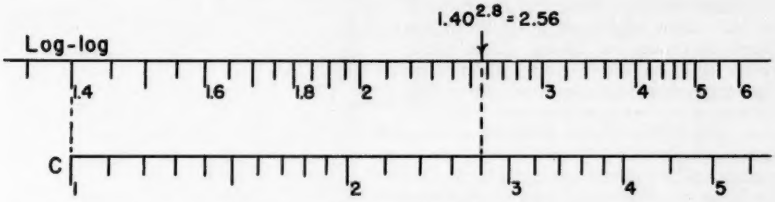

Figure 4. Slide rule with log-log scale.

determined in two steps, one setting for the value of S and one for the value of U. All of the constants have been taken into account in the construction of the scales and need not be entered into the individual computation.

There are functions, however, which are not easily adaptable to special slide rules, an example being

$$H = (S + 6.13)^{0.58} + 2.0\ US.$$

This does not reduce to the form $A + B = C$, in which A, B, and C are separate functions of S, U, and H, as in the above example. Methods of handling such equations as these by graphical devices are discussed in later portions of this paper.

The main drawback to the use of special slide rules lies not so much in the design and construction of a single rule as in the difficulty of duplicating such rules cheaply enough to compete with graphical devices, which are easily duplicated. Thus far, the principal application of special slide rules has been in the field of advertising, where they serve as attention-commanding novelties. Further applications of this method have been described by Davis.[6]

GRAPHICAL METHODS OF SOLUTION

There are three graphical devices which are commonly used for the solution of problems that involve three or more parameters. For simplicity, discussion here of these devices will be limited to problems involving three parameters, but it will be evident that several such devices may be adjoined or otherwise applied in succession for the solution of problems which involve additional parameters.

The simplest of these graphical devices is the common *cartesian graph*, in which values of C are plotted against values of A to form a family of curves, each curve corresponding to a different value of B. The Doolittle formula referred to in the previous section is shown in Figure 6 as a graph, from which values of H may be estimated. Obviously, however, interpolation is difficult in certain portions of this graph because of the nature of the curves and the irregularly spaced intervals between them.

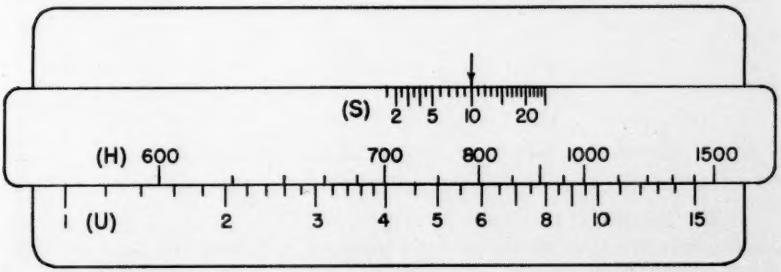

Figure 5. Special slide rule for the Doolittle formula. The slide is moved to place the value of S on the arrow. The value of H is read opposite the value of U.

A more desirable device for computation is that shown in Figure 7, in which the graph is drawn on log-log graph paper rather than on linear graph paper. The log-log graph is easier to draw and to read because of the straight lines and their constant slope. This figure is called a *cross-section chart,* and is referred to by some authors as a type of nomograph. It may be considered here as a type of graph simplified through selection of the coordinate system on which it is drawn.

The third device is the *alignment chart* (Figure 8), in which relationships among the three parameters are realized by means of a straight index line laid across the three scales. It is this device, most commonly referred to as the *nomograph,* with which the remainder of this paper will be primarily concerned. It has recently been shown by Burrows[3] that this form is also a graph of the function, arrived at by selection of the coordinate system on which it is drawn, the system in this case being a form of hyperbolic coordinates.

This form of nomograph is most versatile in its application, being adaptable to any equation which can be expressed in the form:

$A_1(B_2 - C_2) - B_1(A_2 - C_2) + C_1(A_2 - B_2) = 0$, in which A_1 and A_2 are functions of one parameter, B_1 and B_2 of another parameter, and C_1 and C_2 of a third parameter. Any one of these functions may be a constant (including zero). Thus, if $A_2 = 0$, $B_2 = 1$, and $C_2 = \frac{1}{2}$, the above equation becomes $A_1 + B_1 = C_1$, which is the basic equation of the slide rule. However, the form may also be applied to formulas which are not easily adaptable to slide rules, such as the polynomial previously mentioned,

$$H = (S + 6.13)^{0.55} + 2.0\ US.$$

the substitutions being $A_1 = (S + 6.13)^{0.55}/(2S + 1)$, $A_2 = 2S/(2S + 1)$, $B_1 = -U$,

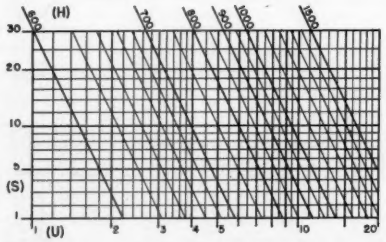

Figure 7. Graph of the Doolittle formula on log-log graph paper—an example of a cross-section chart.

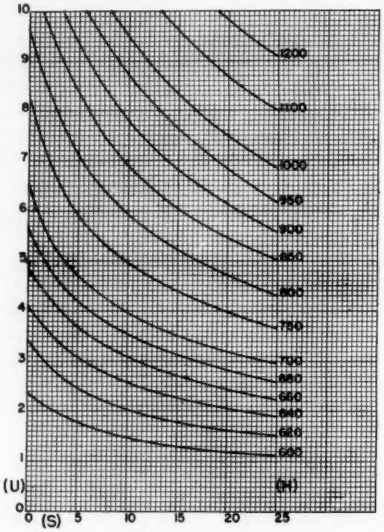

Figure 6. Graph of the Doolittle formula on linear graph paper.

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Figure 8. Nomograph of the Doolittle formula. A straight line drawn to the values of S and U on the extreme scales intersects the corresponding value of H on the internal scale.

ARMY RESERVE RESEARCH AND DEVELOPMENT PROGRAM

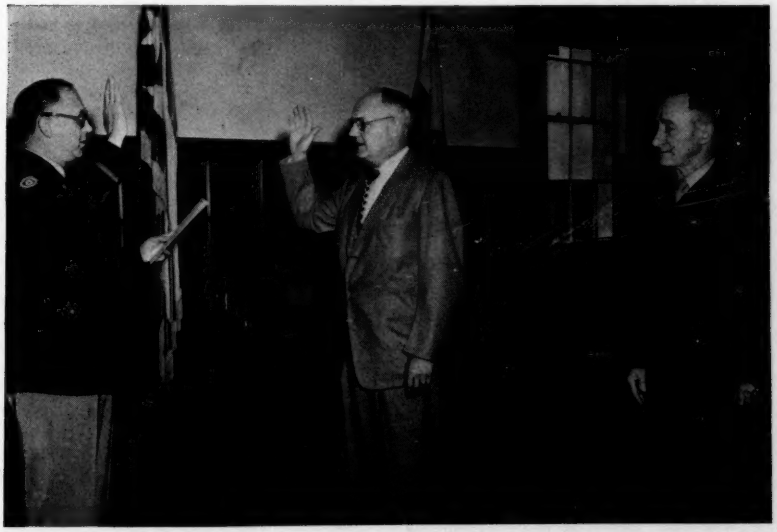
By LESLIE F. ZSUFFA*

One important but little-known phase of research at Georgia Tech is concerned with the conduct of research and developmental programs by faculty members as part of the Army's reserve training program. The following article describes in some detail the significance and scope of the research now being performed in this manner.

Early in 1947, several Army reserve officers connected with the Georgia Institute of Technology established, with the concurrence of the Georgia Military District, one of the first training groups for engineers and research scientists in the United States. Commanded by Lt. Colonel Frank F. Groseclose, professor and director of the Georgia Tech School of Industrial Engineering, the unit was officially designated as Section II of the 342nd Composite Reserve Training Group.

Many engineering and research problems of interest to the Army were discussed by members of this group at its regular monthly meetings. However, since the Department of the Army had formulated no plans at that time for the utilization of the services of such a group, contributions to the research and development program of the Army were made by individual members chiefly through short tours of active duty at various technical installations.

*Georgia Tech Director of Public Relations; Lt. Colonel, QMC-Reserve; Executive Officer, 3107th Research and Development Training Group (Reserve).



Col. Blake R. Van Leer being sworn in as Commanding Officer of 3107 R. & D. Unit by Col. C. C. B. Warden, as Lt. General Alvan C. Gillem looks on.

In the meantime, the National Defense Establishment conducted a survey among approximately 69,000 scientists and engineers to determine their contributions to victory in World War II. Of the 15,000 of this number who had been in uniform, about 4,000 made constructive suggestions as to how to bring about a better utilization of scientifically trained reserve personnel. Among the many suggestions offered, one of the most frequent was that reserve personnel should be provided inactive-duty training during times of peace, training that would be appropriate to their scientific competence and would prepare them for mobilization assignments appropriate to their technical training and experience.

In the early part of 1948, an *ad hoc* committee of reserve officers representing scientific and engineering institutions met in Washington, D. C., and made recommendations to the Department of the Army as to the method for furnishing peacetime training to its reserve officers who are scientific research and development personnel. These recommendations were accepted and incorporated into Department of the Army Circular 127, which was issued and distributed to the field under date of May 5, 1948.*

OBJECTIVES

The two major objectives set forth in Circular 127 are:

1. To establish a program for reserve officers who are professionally qualified in research and development which will:
   a. Maintain the useful affiliation of this type of personnel with the Organized Reserve Corps;
   b. Provide peacetime assignments for these officers, enabling optimum utilization of their education, experience, and skills;
   c. Furnish mobilization assignments which will fully utilize their talents;
   d. Adequately prepare these officers for mobilization; and

2. To establish adequate means for the selection of reserve officers qualified to participate in this program.

*Department of the Army Special Regulations No. 140-190-2 superseded Circular 127 on November 14, 1949.

Two qualifications determine eligibility for assignment to an organized Reserve Research and Development Group. These are (1) training and (2) professional experience. In terms of training, reserve officers eligible for participation in this program must possess at least a bachelor's degree from a college or university accredited by one or more of the organized national or regional educational accrediting associations, or the equivalent in professional experience. In terms of experience, either past or present, the officer must be qualified in a professional capacity in research and/or development work in a field normally associated with one of the physical, engineering, medical, or biological sciences, including pertinent fields of mathematics and psychology.

PRESENT GROUPS

At the present time, 90 groups, each consisting of ten or more officers, have been approved for organization in 35 states and the District of Columbia. In all, 2,924 officers have been approved for assignment to these groups.

In the Third Army Area, groups have been organized at Atlanta, Georgia; Chapel Hill, North Carolina; Gainesville, Florida; Kingsport, Tennessee; Auburn, Alabama; Oak Ridge, Tennessee; Florence, Alabama; Knoxville, Tennessee; and Clemson, South Carolina.

The Atlanta group, which replaced the aforementioned Section II of the 342nd Composite Reserve Training Group in January, 1949, is the only one in Georgia and is designated as the 3107th Research and Development Training Group (Reserve). It is commanded by Colonel Blake R. Van Leer, President of the Georgia Institute of Technology. There are 27 officers presently assigned to this group, with applications from at least ten more now being processed. These officer-scientists come from Georgia Tech, Emory University, the University of Georgia, state and federal agencies, and private research and development laboratories.

Technical services or branches represented include the Chemical Corps, Corps of Engineers, Medical Department, Ordnance De-

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DIGESTS OF GRADUATE THESES

MISCELLANEOUS FIELDS

1948-1949

The following digests represent summaries of theses submitted during 1948-1949 in partial fulfillment of the requirements for the degrees of Master of Science in Industrial Engineering, Master of Science in Industrial Management, Master of Science in Physics, Master of Science in Safety Engineering, and Master of Science in Textile Engineering. This is the last in a series of features designed to present data on the graduate theses submitted last year to the various schools of the Georgia Institute of Technology.

INDUSTRIAL ENGINEERING

Joseph S. Dwyer, *An Analysis of Motion and Time Study Training as Given by Colleges and Industrial Organizations.* Faculty advisor: Professor F. F. Groseclose.

Training in motion and time study is important because of the intimate relation of the subject to all other phases of industrial engineering. The purpose of this thesis was to ascertain the nature and extent of laboratory training in motion and time study as provided for undergraduate students, in the colleges and universities, as well as in leading industrial organizations in the United States.

Results of this investigation disclosed that the relative emphasis placed on motion study and time study is about the same in institutional training, but in industrial training emphasis is on time study rather than motion study. Considerable differences exist in the emphasis on fatigue, while the technique of micromotion study is emphasized more in institutional than in industrial training. Process analysis, operation analysis, stop-watch observation, performance rating, and standard data are emphasized, and to approximately the same degree, in both types of training. Although differences exist between institutional and industrial training, the two show a fair degree of conformance in the coverage of subject matter. *A. S. C.*

W. Dale Jones, *Wage Incentive Payment for Multiple-Machine Assignments.* Faculty advisor: Professor F. F. Groseclose.

The application of the wage incentive method to multiple-machine assignments has been greatly restricted because of the variability of the running cycles of individual machines. The basic problem in providing for incentive payment for the operator of several machines is the determination of the extent of machine idleness caused by "machine interference" (two or more machines being nonproductive at the same time).

A mathematical method of utilizing the laws of probability was developed for the purpose of approximating machine interference idleness for various multiple-machine-assignment conditions. As a means of testing the validity of this method, an interference computer was developed. This equipment simulates multiple-machine assignments and accurately measures both average servicing time per machine and machine interference.

One hundred typical multiple-machine assignments were tested on the interference computer. The consistently close agreement between the mathematically calculated interference and the actual interference for the various assignments proved the validity of the mathematical method as a means of closely approximating machine interference. The solution of this problem then made it possible to develop an incentive plan for multiple-machine assignments which properly allows for the machine interference variable. *W. D. J.*

INDUSTRIAL MANAGEMENT

Everett Richard Bollinger, Jr., *Capital Issues and Their Cyclical Implications, 1919-1948.* Faculty advisor: Professor F. B. Wenn.

Since the flow of securities into United States markets presents a pattern similar to the fluctuations of the business cycle,

it seemed possible that the same factors may influence both situations. Possible correlation was examined by comparing data on total new domestic security issues, new stock issues, new bond issues, new capital issues, and refunding issues with chosen specific measures of production, security price fluctuations, corporate earnings, and interest rates, after smoothing the raw data with an 11-month moving average and determining and removing the trend. It was decided that a graphic analysis rather than a complex study of cause and effect would be sufficient from the financial management point of view.

Apparently, no prediction of stock prices can be obtained from the production index, although patterns for the two generally run parallel. Total domestic security issues also follow a fairly consistent parallel with stock prices, which, incidentally, reflect the level of optimism in the investing public. With respect to capital issues and stock prices, correlation is strong. Bond issues and production are directly related, with a period of about 18 months between the floating of a bond issue and the resulting increase in production. Logically, there is a negative correlation between refunding capital issues and bond yields, since the object behind refunding is to take advantage of a lower interest rate than is being paid on an issue already outstanding. *M. M.*

PHYSICS

Frederick Dixon, *The Impedance-Frequency Characteristics of Quartz Crystals.* Faculty advisor: Dr. W. A. Edson.

Literature on the electrical characteristics of piezoelectric crystals has been sufficiently incomplete to warrant a complex algebraic analysis of the equivalent electrical impedance existing between the terminals of a crystal considered as an independent unit. Mathematic approximations in this study were based on purely electrical considerations, with computational omissions limiting the results to quartz crystals.

Calculations from a few electrical definitions of a crystal progressed through the study of crystal properties with respect to shunt capacitance to developments of impedance functions, which would enable analysis of various circuits including the crystal as a part. Graphs easily sketched from these and further calculations clearly indicate crystal characteristics. These described approximations to true impedance characteristics are not well understood or widely applied in specifying properties of crystals, and many of the more intricate formulas may be reduced legitimately to conventional forms.

Control of the impedance level of a crystal will prove a valuable study, since formulas indicate that this will not materially degrade the intrinsic quality factor of the crystal. However, the formulas derived are important in themselves for use in the solution of circuit problems. Above all, this study provides a basis for further mathematical investigation of crystal performance and application. *M. M.*

Acey LeeRoy Floyd, Jr., *Effect of Temperature on the Crystal Structure of Lanthanum, Cerium, Neodymium, and Praseodymium. The Relation Between Crystal Structure and Superconductivity.* Faculty advisor: Dr. W. T. Ziegler.

Certain anomalies found in the physical properties of the rare earths are attributed to the coexistence of two phases of each metal in the temperature ranges where these irregularities are noted, which indicates that two crystal structures also coexist. Because of the dependence of superconduction and other physical properties on crystal structure, the purpose of this thesis was to investigate certain properties in relation to crystal phases of the four rare earth metals, cerium, lanthanum, neodymium, and praseodymium, and to determine the existence of any allotropic forms having similar properties at room temperature but different superconducting properties at the temperature of liquid helium.

An attempt was made to change the crystal structure of lanthanum and cerium and then to determine superconducting properties by magnetic methods. Two crystal structures (the hexagonal close-packed and the face-centered cubic) were found for lanthanum and cerium. The existence of three allotropic crystal forms of lanthanum at liquid helium temperatures was postulated to explain the observed superconducting properties of this metal, and it was believed that transitions from one phase to another did occur in certain of the ex-

periments. X-ray diffraction studies of neodymium and praseodymium failed to reveal any simple crystal structure. *A. S. C.*

SAFETY ENGINEERING

Webster William Plourd. *Aviation Clock Dial Characteristics in Relation to Speed and Accuracy of Reading.* Faculty advisor: Professor W. N. Cox, Jr.

Any improvement in the aeronautical clock dial design that would facilitate efficient reading would, in turn, reduce the complexity of the pilot's duties and lessen the accident hazard. In this interest, a study was initiated to test the superiority of a counter-pointer dial over a multiple-pointer dial and to determine which design characteristics contributed to efficiency of reading.

Data were obtained by comparison of four dial designs—the conventional 12-hour, a 24-hour, and two variations of a counter-pointer. For proper experimental conditions, new dials were carefully designed with attention to known psychological facts; test apparatus was designed so as to insure sufficient control of factors subject to stabilization; selection of test procedure was based upon similarity to actual conditions; and test subjects were chosen from pilots and nonpilots.

Mathematical calculations from records made of the speed and accuracy in dial readings indicated that one of the original counter-pointer designs was superior in both respects to all of the other designs. The conventional dial was read with the least speed and accuracy. Difficulty of interpretation arose from three particular details; viz., the 12-hour scale, the small distance separating hour numerals, and the counter window's being obscured at certain times by the minute hand. Numbers placed at ten-minute intervals were as effective as those at five-minute intervals. Further research should be conducted to determine optimum position and size of a counter window, and dials should be tested under varied operating conditions. *M. M.*

TEXTILE ENGINEERING

Shao-Lee Soo. *A Study of the Effect of Lubrication on the Dynamics of Spinning Spindles.* Faculty advisor: Dr. J. L. Taylor.

Successful and economical spinning operations depend to a great extent on the satisfactory performance of spindles. The modern trend toward high spindle speeds and large packages has aggravated the interrelated problems of power consumption, vibration, and lubrication. The purpose of the investigation presented in this thesis was to combine a theoretical study of dynamics as involved in fundamental spindle design with the evaluation of experimental results of factors such as speeds, vibration, lubrication, power consumption, and oil throwing.

From the work reported here, it was concluded that there is a narrow optimum speed range of minimum mechanical vibration for each design of spindle. Linear vibration of a spindle is affected by the lubricating oil used, and greater damping effect can be expected by employing heavier oil when operating at near-critical speeds. Power consumption for driving a spindle is much greater when heavier oil is used and is also greater when operating near the critical speed. Oil throwing was found to be mainly the result of using more oil than necessary. *A. S. C.*

METALLURGICAL RESEARCH AT GEORGIA TECH

Continued from Page 4

A variety of loads ranging from 0.5 to 500 grams may be used, making possible the testing of a wide variety of materials.

The sample, clamped in place as noted above, is examined under the microscope in the conventional manner. After an area for test has been selected, the objective lens of the microscope is replaced with a special holder which carries a diamond pyramid penetrator. The stage of the microscope is then carefully lowered, bringing the penetrator into contact with the test area of the sample with sufficient force to raise the lever which supports the specimen and the

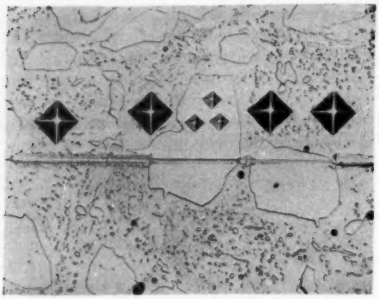

Figure 3. Micrograph showing microhardness penetrator impressions and scratch on a high-chromium steel (550X). Light areas are carbide constituents.

load. This movement is indicated by the extinction of a small lamp (10) when a circuit contact (9) is broken.

After a short time, the stage is raised, releasing the load, and the penetrator is replaced by the objective lens. The test area is brought into focus, and the diagonal of the penetrator imprint is then accurately measured. The hardness of the test area, H_{vp} (Vickers number), in kilograms per square millimeter, is related to the diagonal, d (measured in 0.001 millimeters), and the applied load, P (in grams), as follows:

$$H_{vp} = \frac{1854 \times P}{d^2} .$$

A high H_{vp} denotes a hard substance and a small penetrator impression.

If desired, the sample may be moved in line across the diamond, producing a scratch whose width from point to point within the test field is an indication of the hardness of the constituents it traverses. Scratch hardness testing with the Bergsman tester is limited to a load range of 0.5 to 5 grams.

Results of penetration and scratch hardness tests on a high-carbon, high-chromium steel are shown in Figure 3 at a magnification of 550X. The loads employed for indentation and scratch tests were 50 grams and 2 grams, respectively. The hard carbide constituent and the soft ferrite matrix exhibit Vickers numbers of 1,280 and 240, respectively.

GEORGIA TECH RESEARCH

Current research in the field of physical metallurgy at Georgia Tech is concerned with a study of titanium-rich alloy systems. The current nation-wide interest in titanium is the natural result of the availability and certain characteristics of the metal. Many problems do exist, however, relative to the production of this metal in fairly pure form.

Titanium is the fourth most abundant element of structural value and is widely available in its oxide form in the United States and Canada, as well as in other localities throughout the world. Active development of the Allard Lake ilmenite deposits of Quebec (which contain about 35 per cent TiO_2 and 40 per cent Fe, largely as Fe_3O_4) is being jointly undertaken by the Kennecott Copper Corporation and the New Jersey Zinc Company. [1] The National Lead Company is currently working the MacIntyre ore body in the Adirondack Mountains of New York, producing titanium sponge. Together with the Allegheny-Ludlum Steel Corporation, this company has organized the Titanium Metals Corporation for the purpose of producing forgings and bar, sheet, strip, and wire forms from ingots of titanium-rich alloys weighing up to 500 pounds.

The E. I. du Pont de Nemours & Company, Inc., has recently leased lands in north-central Florida from that state, to augment its ilmenite reserves for titanium production. The Remington Arms Company, an affiliate of this company, is handling developments in the melting, casting, and fabrication of the metal.

Titanium has a density intermediate between aluminum and iron. It has shown complete resistance to attack by sea water after four months at Kure Beach, North Carolina, under various types of exposure (immersion, partial and complete, and different concentrations of spray exposures). It exhibits mechanical properties comparable to normalized low carbon steels (80,000 psi. tensile strength, 74,000 psi. yield strength at 0.2 per cent elongation, and 30 per cent elongation in two inches), and is a fairly workable, weldable, and machinable material. Titanium has good alloy compatibility with a number of elements, and,

since it undergoes an elevated temperature transformation in the vicinity of 1,615° F., possibilities are good for modification of properties by alloying and heat treating. [2] [3]

Initial research at the Georgia Institute of Technology involves a study of the titanium-copper system up to five per cent copper. Small melts will be prepared in the furnace portrayed in Figure 4, which is a type commonly used in melting highly reactive metals and alloys.

The charge to be melted (in this case, about 0.25 pound of titanium sponge and the desired proportion of high-purity copper) is placed in the depression of the water-cooled copper hearth plate. The cover is tightly fastened in place, and the system then flushed with helium gas. Actual melting is accomplished by the heat of an electric arc drawn between the water-cooled, tungsten-tipped electrode and the charge. The energy for the arc is supplied by a conventional arc welding transformer which has a rating of about 600 amperes. Samples so prepared are annealed under a protective atmosphere in a small tube furnace in order to improve homogeneity of composition and structure.

The equilibrium room-temperature solubility limit of copper in titanium will be determined by microscopic and X-ray diffraction studies of a series of alloys of increasing copper content. Crystallographic, microstructural, and hardness characteristics of the second phase which appears when the solubility limit is exceeded will also be studied.

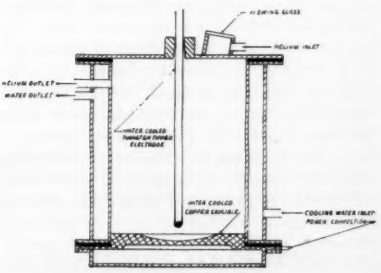

Figure 4. Proposed water-cooled arc furnace for melting of experimental heats of titanium-copper alloys.

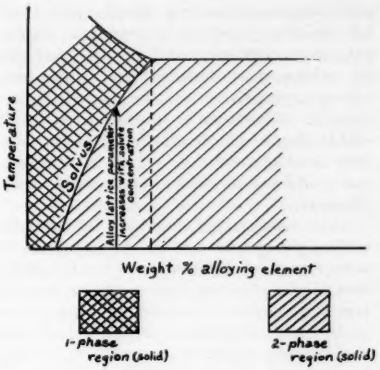

Figure 5. Typical solvus line of an equilibrium phase diagram.

The effect of increasing temperature on the solubility limit (the solvus line of the terminal titanium-rich solid solution) will be studied by employing samples of various copper content which will be heated to different temperatures, held at each temperature to establish equilibrium, and then rapidly quenched to room temperature. Specimens containing copper in excess of the room-temperature solubility limit will exhibit a single phase structure when soaked and quenched from the solvus temperature or slightly higher. Similarly, the lattice parameter of the solvent (titanium), varying as it does with an increase in solute concentration to saturation, may be used to establish points on the solvus line. This is schematically represented in Figure 5.

The effect of copper content on the allotropic transformation temperature of titanium-copper alloys will also be determined by using metallographic, X-ray diffraction, and thermal analysis (cooling curved) techniques.

Having determined the above-noted equilibrium characteristics of the titanium-rich portion of the titanium-copper system, the response of alloys to heat treatment will then be studied. Solid-solution alloys whose solubility of the solute element decreases with decreasing temperature, as shown by the solvus line of Figure 5, are potential age-hardening materials. If by a practical

quenching treatment a specific alloy can be caused to exist in a metastable supersaturated condition, and if precipitation can be subsequently induced and controlled, strength properties may be materially increased. Considerable experimental work will be required to determine optimum solution heating conditions (time at temperature), quenching rate, and aging temperature.

The information described in the preceding paragraphs can all be obtained by using small, 0.25-pound melts. Investigation of the effect of copper content on the tensile properties of titanium-copper alloys, both in the equilibrium-cooled and the heat-treated conditions, would necessitate larger heats and is therefore not included in the initial program.

Results of some exploratory work have recently been reported[4] for the titanium-copper system up to a copper content of five per cent. No exhaustive study has previously been undertaken, however, and basic information such as is proposed in the Georgia Tech program is needed for a complete evaluation of the potentialities of these alloys.

Metallurgical studies on other materials will be undertaken as time goes on, and it is hoped that the facilities now available here will serve as an increasingly valuable tool for education and research.

ACKNOWLEDGMENTS

Figures 2 and 3 are reproduced through the courtesy of the Uddeholm Company of America, Inc. Titanium sponge for the initial experimental heats has been supplied by the Titanium Alloy Manufacturing Division of the National Lead Company.

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GRAPHICAL METHODS OF COMPUTATION

Continued from Page 8

$B_3 = 1$, $C_3 = H$, and $C_2 = 0$. This form, then, has the advantage of greater versatility than the special slide rule. At the same time, such a nomograph is at least as easy to devise and construct, and can be duplicated at far lower cost.

Many who are aware of the greater accuracy with which they can make certain calculations on the slide rule quite justly point with disparagement to the nomographs appearing in handbooks, textbooks on graphical methods, etc. It should be borne in mind, however, that most of the nomographs appearing in the literature have been put there (1) for the purpose of showing how such a nomograph can be prepared and (2) for limited computation over a wide range of the various variables. Furthermore, these nomographs are usually constructed with the knowledge that they will be subject to considerable reductions in size during the printing process, hence they cannot be drawn with too fine detail. If a nomograph is actually to be used for routine calculations in a plant or laboratory, it should be specially prepared for that particular use—drawn to cover only the ranges involved and in sufficiently fine detail to give all of the accuracy required, or at least all that is justified by the original data from which the nomograph's basic formula is evolved. Prepared in this manner, the nomograph can be considerably more accurate than the average-length slide rule, and a great deal faster in yielding results.

FUNDAMENTAL PROBLEMS OF NOMOGRAPHY

The two fundamental problems involved in representing a given formula by a suitable nomograph are (1) finding an arrange-

ment of scales and index line(s) which is capable of realizing graphically the numerical relationships inherent in the formula, and (2) making the necessary adjustments in moduli and distribution of the scales to accommodate the particular ranges and degrees of accuracy required for the data to which the nomograph is to be applied.

It is usually possible to obtain a solution of some sort to the first problem, but the resulting nomograph may be so intricate as to be virtually useless for rapid calculation. In this case, it is frequently more satisfactory to employ a cross-section chart, a simple graph, or a table of values. This point is rather a difficult one to decide without a great deal of experience with nomographs. A review of the methods employed to date indicate two principal lines of attack on the problems involved, the *synthetic* method and the *analytic* method.

The Synthetic Method

Of these lines of attack, the synthetic method has seen the greater service. Mention of it is to be found in the older treatises of d'Ocagne[7] and Lipka[11] and in the recent works of Davis[6] and Douglass and Adams.[8] Indeed, this method has been so thoroughly developed that further texts on this subject seem purposeless. Nevertheless, they continue to appear.

The thesis of the synthetic method is simple: one has only to investigate all possible arrangements of scales and index lines and to determine the relationships existing among their geometrical elements. If an arrangement is found whose elements can be expressed as functions of the variables in the formula in such a way that the one element can be substituted for the other without destroying the original relationship, then that arrangement may be employed in constructing the nomograph. Unfortunately, the number of such arrangements becomes quite large, and one finds it necessary to keep handbooks of forms previously investigated in order to decide expeditiously in favor of the form considered most satisfactory. The upshot of this is that most of the books on the synthetic method degenerate into mere catalogs of forms, with a great deal of repetition and very little originality.

After the most suitable form has been selected, using the synthetic method, one then sets up the functions to be substituted for the geometrical elements, inserts the limits of each variable, and calculates the resulting scale lengths and moduli. If these are not such as to provide the necessary degree of accuracy and compactness, it is then necessary to make further substitutions, the new functions including certain arbitrary variables. Then, by means of equations derived from the desired dimensions of the nomograph, the necessary values of these constants are determined, after which it is possible to insert the second set of substitutions and to construct the nomograph.

The Analytic Method

This method was employed in part by Hewes and Seward[9] in 1923 and later by Allcock and Jones[1] and Mavis.[14] The approach used here is deductive, as opposed to the inductive approach of the synthetic method. The index line is a straight line, intersecting scales representing the variables U, V, and W. The points of intersection of index line and scales have the coordinates (x_u, y_u), (x_v, y_v), and (x_w, y_w), respectively. Since the relationship of three such points lying on a straight line is $y_u(x_v - x_w) - y_v(x_u - x_w) + y_w(x_u - x_v) = 0$, the problem of finding a suitable form for the nomograph becomes a problem of expressing these x's and y's as functions of the U, V, and W of the original formula so that when they are substituted in the above expression the resulting sum will be zero for all corresponding values of those variables. The geometrical form of the nomograph is thus determined by the functions chosen, rather than the reverse.

The simplification does not end there, however. Since each x occurs twice in the above relationship, it is a bit difficult to determine in some cases the best method of expressing the x's and y's as functions of the variables of the formula. A quicker approach is made through use of the determinant form of this relationship,

$$\begin{vmatrix} y_u & x_u & 1 \\ y_v & x_v & 1 \\ y_w & x_w & 1 \end{vmatrix} = 0, \qquad (1)$$

in which each x and y occurs only once. The procedure for finding the functions which may be substituted for these x's and y's is then quite direct. Suppose that the formula to be represented is the reduced cubic equation, $U^3 + VU + W = 0$. This is expressed in determinant form as

$$\begin{vmatrix} U^3 & U & 1 \\ -V & 1 & 0 \\ -W & 0 & 1 \end{vmatrix} = 0. \qquad (2)$$

This determinant may be manipulated by standard procedures to obtain a determinant whose third-column elements are all 1's:

$$\begin{vmatrix} \frac{U^3}{U+1} & \frac{U}{U+1} & 1 \\ -V & 1 & 1 \\ -W & 0 & 1 \end{vmatrix} = 0. \qquad (3)$$

This last determinant is referred to as the *defining equation* of the nomograph. Each element in this determinant is set equal to the corresponding element in the determinant of Equation 1: $y_u = U^3/(U + 1)$, $x_u = U/(U + 1)$, $y_v = -V$, $x_v = 1$, $y_w = -W$, and $x_w = 0$.

The numerical values of U, V, and W determine the values of the corresponding x's and y's for the construction of the scales. The geometrical figure is obvious upon inspection of these functions: the V- and W-scales are parallel and linear, since they have the constant abscissas 1 and 0, respectively, and ordinates $-V$ and $-W$, respectively. The U-scale is curved, since its ordinates and abscissas are both nonlinear functions of U. For all positive values of U, the U-scale lies between the V- and W-scales, since the abscissa $U/(U + 1)$ lies between 0 and 1 for all positive values of U. Thus is the first problem of nomography easily solved, the problem of finding a geometrical arrangement of scales and index line which will realize the numerical relationships implied in the formula.

The second problem, that of adjusting the moduli and positions of the scales to accommodate the particular ranges encountered in the data to be represented, must be approached algebraically, if one is to adhere to the above form of defining equation. The method employed by Allcock and Jones[1] and Mavis[14] consists in multiplying the determinant of the defining equation by a nonvanishing matrix containing nine (or sometimes less) constants. The product is then a defining equation whose elements contain these constants, and the values of the constants are determined by solution of an equal number of simultaneous equations derived from the desired dimensions of the nomograph and the limiting values of the U, V, and W. This may occupy quite a few sheets of scratch paper and consume no little time, as one may discover by following the examples worked out by those authors.

The necessity for this algebraic step arises from the fact that the defining equation is given in terms of cartesian coordinates which lack flexibility, whereas, in order to represent all possible ranges of its variables, the form of the nomograph must be very flexible. To avoid this difficulty, a type of "hyperbolic" coordinates has been described by Burrows[3] and applied to the construction of nomographs. The use of these latter coordinates eliminates the necessity for making changes in the defining equation as described above. Instead, the defining equation is used in the form in which it appears in Equation 2, and all necessary adjustments of moduli and positions of scales are made by selecting an optimum value for a single constant, r. The selection of this value is usually quite simple; methods of making this selection and plotting the scales of the nomograph are discussed in the above mentioned reference.[3]

As yet, the analytic method has been applied primarily to a single category of forms, those in which a straight index line intersects three scales. This would seem to limit the method unduly. Apparently, however, such is not the case, as there is not a single formula treated in any of the books in the attached bibliography which cannot be represented in this category.

The versatility of this form may be better realized from a consideration of some of its possibilities: the three scales may be parallel, concurrent, N-shaped, H-shaped, straight, hyperbolic, parabolic, elliptical, exponential, etc., all of which are "different"

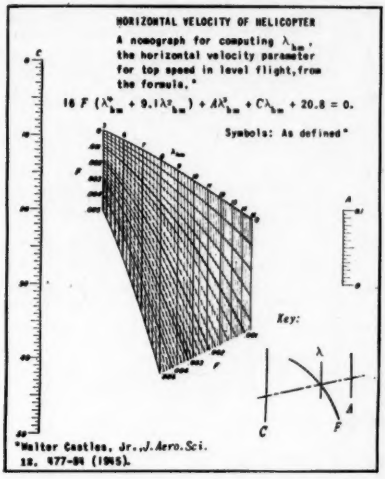
HORIZONTAL VELOCITY OF HELICOPTER
A nomograph for computing λ_{hm}, the horizontal velocity parameter for top speed in level flight, from the formula,*
$16F(\lambda^4_{hm} + 9.1\lambda^2_{hm}) + A\lambda^2_{hm} + C\lambda_{hm} + 20.8 = 0.$
Symbols: As defined*
Key:
*Walter Castles, Jr., J. Aero. Sci. 12, 477-84 (1945).

Figure 9. Nomograph for obtaining the horizontal velocity parameter for top speed in level flight of a helicopter.[5]

forms by synthetic methods. The subdivision of these scales may be linear, logarithmic, hyperbolic, exponential, etc. Furthermore, a given scale may represent more than one variable by means of a network-scale device (Figure 9), or by being at once an element of two portions of a compound nomograph.

The combination of analytical approach and the use of hyperbolic coordinates constitutes a most expeditious method of constructing nomographs. By the analytic approach the arrangement of geometrical elements to be used is arrived at *deductively;* by the use of hyperbolic coordinates the necessary scale moduli and positions are attained by variation of a single constant of the coordinate system. The construction of the nomograph shown in Figure 9 was simple by this method; it was quite difficult when approached by the synthetic method or the analytic method based on cartesian coordinates.

LIMITATIONS OF NOMOGRAPHS

The use of nomographs has often been "oversold" by failure of authors to point out the limitations of certain nomographs in particular and all nomographs in general. To return to the example of the Doolittle formula, which was represented graphically in Figure 6, the reader will recall that it was possible to represent this formula by cross-section chart (Figure 7) only because the functions of S, U, and H involved could be represented in terms of an A, B, and C, in such a manner that $A + B = C$. It was possible to represent the same formula nomographically because its functions could be expressed in terms of the x's and y's of Equation 1. In both cases, the realization of numerical relationships among the three variables was greatly expedited by the simplification of the graphical form. However, it must be remembered that not all formulas can be represented by these methods. There remain some cases which can be handled best only by means of a common graph.

One should also be cautious about applying a nomograph whose origin and ancestry are vague unless the nomograph has been checked against known relationships of the data involved. All too frequently, the formula on which a nomograph is based is omitted from printed copies, or, if included, is stated without reference to its origin in the literature, the ranges of the variables from which the relationship was derived, or the limits of error in the original data. Consequently, a formula or its nomograph may be misapplied to data lying outside the ranges of the original data, or used to obtain results whose apparent accuracy is entirely unjustified by that data.

As a means of avoiding these difficulties, every nomograph intended for plant or laboratory use should have printed on it: (1) a title which states the purpose of the nomograph in terms that are unlikely to be misconstrued, (2) the formula it represents, together with the definitions of all symbols involved, (3) all pertinent literature references, (4) the limits of error of the original data, and (5) complete instructions for use. Finally, while the ranges of the variables represented may be considerably reduced in order to provide greater accuracy, these ranges should always lie within the limits of the original data.

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ARMY RESERVE RESEARCH

Continued from Page 10

partment, Quartermaster Corps, and Signal Corps. The group is organized by military as well as specialized functions; the general staff officers carry out the same functions as those of any other military unit. Special staff officers head the various technical and scientific fields in which research or development projects may be undertaken.

PROJECT SELECTION

Members of the group are encouraged to undertake research projects that tie in with their civilian occupations and are of benefit to one of the technical services of the Army. The greatest contribution which members of the group can make, at present, is primarily in the field of nonmaterial research. At the outset of every research project, it is usually necessary to make a search of literature on the subject to determine, insofar as practicable, the work which has previously been performed in the field and which is applicable to the problem at hand. Material-research-type projects are conducted when it is determined that officers have access to laboratories, machine shops, or other facilities which are necessary in work on the problems in question.

Of aid to the group is a book of the Department of the Army Logistics Division which gives more than 650 project titles for suggested areas of research and development which are of definite interest to the technical services. Several of these have already been assigned to the group, and others are under consideration. The major scientific fields and their subfields covered by these project titles are as follows:

Major Scientific Fields	Subfields
Biology	Medicine
	Dental
	Psychology
	Veterinary, Animal Husbandry, Parasitology, Entomology, Zoology
	Microorganisms (Bacteriology and Mycology)
	Botany, Forest Management
	Agronomy
	Food Technology
	Agricultural Engineering
Engineering (Mechanical)	Administrative
	Instruction (Sales Experience)
	Engine—Internal Combustion and Rocket

	Aerodynamics
	Automotive and Heavy Mobile
	Production Processes
	Ordnance Material
	General Subjects
	Heat, Power, Etc.
	Structures
Physics	General and Specialized fields
Engineering (Electrical)	Administrative
	Instructional (Sales Experience)
	Communication—Wire
	Communication—Radio
	Radar Systems and Equipment
	Navigational Aids
	Power Plant and Distribution
	Sound Applications
	Electronics—General
	Test Range Instrumentation
	General
	Thermionics
Chemistry and Chemical Engineering	Ceramics
	Metallurgy
	Mining
	Electrochemistry
	Atomic
	Nuclear
	Health and Safety (Atomic)
	Biochemistry, Food Chemistry, Nutrition
	Pharmaceuticals
	Chemistry—General
	Paints, Resins
	High Polymer, Plastics, Rubber, Textile
	Paper and Wood Pulp
	Rocket Propellants and Explosives
	Fuels
	Petroleum—Chemistry, Engineering, Geology
Geology	General and Applied
Geography	General and Applied
Engineering (Civil)	Water Supply, Sanitary, Hydraulics
	Buildings, Structures
	Roads, Airports
	Soil Mechanics
Engineering (Industrial and General)	Industrial Engineering
	Patent Lawyers
	Administrative and Personnel
Mathematics	General and Applied
Service	Artists, Translators, Writers

Conduct of the research and development activities of the Army, within the scope of policy and objectives established by the General Staff, is a responsibility of the respective technical services. In general, research and development in weapons and equipment are directed toward obtaining the following characteristics: a decrease in both size and weight; adaptability to transport by man and aircraft; increased simplicity of design for operator efficiency; interchangeability of components and parts; ease of maintenance; use of standard commercial components when practicable; production of items of use to the civilian economy; minimum use of scarce and critical materials; and ease of production in quantity.

RESEARCH PROJECTS

Specific research and development projects (phases of several of which have been assigned to the 3107th Research and Development Group) are directed toward fulfilling the following requirements:

1. Air transport of the standard infantry division.

2. Effective aerial resupply of large units.

3. Short-, medium-, and long-range antiaircraft weapons useful against targets traveling at supersonic speeds.

4. Operationally effective surface-to-surface and surface-to-air guided missiles and necessary facilities and instrumentation in connection therewith.

5. A superior line of armored vehicles.

6. Weapons and ammunition having increased armor-piercing capabilities.

7. A series of field radio sets permitting intercommunication among all command echelons.

8. Superior, light-weight wire communication and terminal equipment, including facsimile.

9. Radar fire-control equipment.

10. Improved individual equipment, clothing, and shelters for all environmental conditions.

11. A suitable low-temperature polymer for use as a rubber substitute in cold climates.

12. Reduction of food rations in size, weight, and numbers, with emphasis on nutritional value and acceptability.

13. Light, high-capacity stream-crossing equipment.

14. Improved construction equipment and materials for airfield and road building.

15. Mine-detection equipment for location of all known types of mines and mine-clearing equipment.

16. Individual and collective protective equipment against all known toxic agents, including detecting devices.

17. Effective prophylaxis and treatment methods and agents for epidemical diseases and cold injuries.

18. Improved field medical equipment, smaller, lighter, and suitable for transport by air.

AREAS OF RESPONSIBILITY

Areas of research and development responsibility have been assigned to the various technical services of the Army as follows:

Chemical Corps

Primary cognizance in the field of toxicological warfare and in the fields of incendiary materials; screening agents and smokes; flame agents; toxic fillers; and all devices, methods, techniques, and procedures used solely for their offensive employment, together with all defensive measures in these fields, has been assigned to the Chemical Corps. This corps has also been assigned primary cognizance for the detection of pathogenic and toxicological agents, and for individual and collective protection (except clothing) of military personnel and civilian populations against the use of all pathogenic and toxic agents and materials, incendiary materials, and flame agents. The Chemical Corps is also responsible, where applicable, for the decontamination of personnel, material, supplies, terrain, and facilities exposed to pathogenic and toxic agents and materials.

Corps of Engineers

The Corps of Engineers conducts research, design, development, and tests on materiel, methods, and techniques relating to the following fields: mapping, charting and geodesy including photogrammetry, surveying, photolithography, and drafting; electric power and lighting including searchlights and reflectors; earthmoving and heavy construction; soil mechanics including stabilization, compaction, and trafficability; snow, ice, frost, and permafrost; airfield surfacing; water supply; fire fighting; gas generation; petroleum handling including storage and distribution; compressed air; structures, prefabricated and fixed including fortifications and protective structures; infra-red; ground navigation; camouflage including deception and simulation; bridging and tactical stream crossing equipment including applicable marine craft, cableways, and tramways; obstacles and mine and obstacle clearing, including mine detectors and demolitions; barrage ballons; refrigeration and air conditioning; insect and rodent control; basic materials including plastics and substitutes for critical items; and appropriate basic research.

Medical Department

At present and in the foreseeable future, the major problems of the Medical Department in research and development fall within the following fields:

1. Traumatic surgery, including resuscitation, operative care, convalescence, and rehabilitation;
2. Psychoneurosis, its prevention and treatment;
3. Radiation casualties, prevention and treatment;
4. Cold-weather operations;
5. Special disease problems, such as respiratory infections, diarrheal diseases, infectious jaundice, kala azar, malaria, typhus, etc.;
6. Antibiotics and their use in the prevention of wound infection and treatment of disease;
7. Immunization;
8. Physical standards;
9. Dental caries; and
10. Development of air transportable, lightweight, medical equipment for mobile medical units.

Ordnance Department

The mission of the Ordnance Department in the field of research and development is to plan, supervise, and execute forward-looking research and development programs on new and improved ordnance materiel and materials; maintain complete liaison and close cooperation with the using arms and services, and with every resource of science, technology, and invention to further the effectiveness of ordnance materiel; conduct all activities pertaining to the acquisition, evaluation, and application of

technical ordnance intelligence, both foreign and domestic; control release of all ordnance technical information to foreign and domestic agencies; maintain the Ordnance Book of Standards; and consider and recommend technical action upon all matters affecting materiel coming within the jurisdiction of the Ordnance Department, designed for and intended to be issued to the armed forces.

Responsibility is assigned to the Ordnance Department for research and development programs on materials, development of fuels and lubricants, ballistic research, and preparation of ballistic data; research and development of all guided missiles assigned to the Ordnance Department, free flight rockets, propulsion units including components and propellants, and rocket launchers and related accessories; research and development of all combat, transport, and other automotive vehicles; of cannon above 20 mm., carriages, mounts, test mounts, mortars, recoil mechanisms, carts, caissons, limbers, timekeepers, fire control and optical instruments, and submarine mines; of machine guns and machine gun mounts up to and including 20 mm., hand carts, rifles, submachine guns, pistols, hand arms, light armor, paracrates, pyrotechnic projectors, and recoilless rifles; and of ammunition including components and propellants therefor, bombs, grenades, pyrotechnics, land mines, fuses, explosive devices, and all related accessories.

Quartermaster Corps

The areas of research and development responsibility in the Quartermaster Corps fall primarily into five groups—enviromental protection; textiles, clothing, and leather items; mechanical products; fuels and lubricants handling equipment; and chemical and plastic products. In enviromental protection research, the QMC conducts studies and analyzes climatic and environmental conditions as they relate to QMC supply and service, and studies man-response to world-wide environmental conditions and develops methods of maintaining man as an efficient agent under all conditions to be encountered in modern warfare. The QMC is responsible for the development and production of all types of functional clothing, as well as service clothing, except for certain specialized equipment of the Air Forces; research and development of basic items of cold climate textiles other than outer clothing, including underwear, socks, sweaters, sleeping gear, and handwear; improvement of service footwear and development of various types of functional footwear required for special climatic conditions; proper application of materials to the improvement of military fabrics and their finishes; and the use of sound engineering principles in the research programs on the manufacturing and weaving of textiles.

In the mechanical field, generally, the QMC has responsibility for materials-handling equipment, food preparation equipment, laundering and cleaning equipment, refrigeration for food, and furniture and furnishings. Quartermaster research and development in the fuels and lubricants field is concerned primarily with the design and development of more efficient equipment for dispensing and storing fuels and lubricants in the combat zone, with special study of portable and mobile pumping units, collapsible hose, auxiliary equipment and accessories, and research in the processes for congealing and reconstituting fuel. In the field of chemistry and plastic products, work is being conducted in the fields of coated fabrics, plastic compositions, protective finishes, chemical processes, and biological control agents for sanitation.

Signal Corps

The Signal Corps is responsible for the conduct of research and development in the fields of thermionics, wire communications, radio communications, radar, direction finding, navigation aids, radiological instrumentation, guided missiles instrumentation, sound and light, infra-red meteorology, photography, and ancillary devices pertaining to these major fields. The Signal Corps also conducts and supports basic and applied research in the fields of electrical, magnetics, ionic, molecular, atomic, and nuclear physics; atmospheric physics; organic, inorganic and physical chemistry; minerology; seismology; climatology; geomagnetism; electromagnetic theory and wave propagation; and mathematics.

Transportation Corps

The Transportation Corps prepares and coordinates military characteristics for highway vehicles for which it has requirements for submission to the Ordnance Department, which has primary cognizance in this field; conducts research and development of highway equipment other than vehicles, components, methods, and tests; designs passenger and cargo vessels not exceeding 200 feet in length and about 1,000 tons; prepares and coordinates military characteristics for materials-handling equipment for submission to the Quartermaster Corps, which has primary cognizance in this field; and conducts research and development of rail equipment of all types, motive power, general rolling stock, tools, equipment, and components.

Because of its general nature and the obvious interest of all research and development agencies in this field, primary responsibility for general research is retained by the Deputy Director of Research and Development, Logistics Division, General Staff, United States Army. Phases of this general research include operations research, warfare of the future, business management, psychological research, and environmental research. The actual investigations and research programs are assigned to two or more technical services interested in the various phases of these items. For example, atomic energy and fission products cannot be considered as a whole by any one technical service, so that various phases of this subject, such as decontamination, instrumentation, protective construction, etc., are assigned to various technical services.

The Reserve Research and Development Training Groups are unique in the Army's reserve program in that the primary objective is not unit or individual military training but the assembling of scientists and engineers to be trained to assist in the Department of the Army's research and development program. General military training is limited to the orientation required to enable the officer to function within the research and development portion of the military establishment in case he is called to duty therein.

The technical portions of the group's training program occupies the majority of the training time of each officer. This training may include scientific lectures to the group as a whole and/or work on assigned projects, which may require split assemblies. Actual projects may originate as suggestions from individuals, project sections in the group, or from the group itself; they may be requested from the published project list; or the Department of the Army may formulate projects for assignment to a group or to an individual in the group. The nature of the projects will in many cases be the determining factor in choosing the place of group or section meetings, since library work must be done in a library and laboratory research in a laboratory.

The contribution of the Research and Development Groups to the Department of the Army and its technical services has already proved valuable, and it is anticipated that this contribution will grow with the passage of time.

RESEARCH PUBLICATIONS

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ENGINEER, which renders a running account of Georgia Tech research.

The publication of research results is the only way in which a permanent record can be made available to all.

STATION NEWSBRIEFS

In order better to correlate the administration of research projects, the Station has recently instituted the organization of formal divisions in major fields of science and engineering.

Head of the newly created Chemical Sciences Division is Dr. Herschel Herbert Cudd, former director of the Lantuck Division of the West Point Manufacturing Company. A 1933 Texas A. & I. graduate in chemistry, Dr. Cudd received his doctorate degree at the University of Texas in 1941. He has served as a research chemist for E. I. du Pont de Nemours & Company, as supervisor of inorganic research for the International Minerals and Chemical Corp., and as research chemist for the West Point Manufacturing Company.